Energy Audit of
Shram Shakti Bhavan

Final Report
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PREFACE

Large commercial office complexes consume electrical energy mainly for lighting, space cooling and space heating. Energy audit or carrying out a thorough review into energy consumption patterns for different end-uses to determine points of wastage and points where energy can be conserved, has been used extensively in developed countries to substantially reduce the energy consumption in commercial complexes. In India, energy audit has been initiated primarily in some industrial units while audit of energy in commercial buildings is still in the initial stages.

The energy audit of Shram Shakti Bhavan, which houses the Department of Power, Ministry of Labour and Ministry of Water Resources, has been carried out at the request of the Department of Power. We are grateful to Mr. S. Rajagopal, Secretary, Department of Power, and Mr. K.L. Puri, Adviser, Energy Conservation, Cabinet Secretariat, for giving us this opportunity to carry out the energy audit. We hope that the recommendations given in this report will receive serious consideration and we would be happy to be a part of the implementing process in order to monitor the energy savings that we hope would accrue.

R.K.Pachauri
Director
Tata Energy Research Institute

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Replacing incandescent lamps on second floor with compact Fluorescent lamps could save 5498 kWh.

rconditioning

The role of the central air-conditioner plant in Shram Shakti Bhavan needs to be re-evaluated. Shutting down this plant would save about 44,623 kWh, without significantly affecting occupant comfort in the seven rooms presently conditioned by it.

Of 57 air-conditioners checked randomly (67% of the total), 45 air-conditioners had dirty filters. Regular cleaning of filters could save 5,508 to 8,022 kWh.

Each 1.5 ton air-conditioner having faulty thermostat will consume about 1152 kWh extra per cooling season.

An air-conditoner of 1.5 ton which has lost its coolant will consume about 3326 kWh per cooling season without delivering effective cooling.

pace Heating

Replacing two single rod radiant heater by one convective heater in rooms having two or more single rod heaters can save 26,532 kWh

Replacing each twin rod radiant heater by one convective heater can save 10,930 kWh

Carrying out these recommendations would reduce annual nergy consumption of Shram Shakti Bhavan by 19.8 - 29.8 per cent.

peration and Maintenance

The audit revealed that there was little being done by way f proper housekeeping such as the cleaning of windows, the aylight shelf, tubelight fixtures etc. A large number of rooms ad fixtures from which the covers had been removed. The location f coolers and their cleanliness left much to be desired. There s no proper organization of floors/wings and distribution boxes n different parts of the building. The switches in most of the ooms are in locations which are difficult to access.

Another important point was the fact that even though Shram hakti Bhavan has six packaged air-conditioning units of 7.5 tons ach (four are in operation at any time), servicing a total of even rooms on the first and second floors, these rooms have an dditional 15 window air-conditioners. An exercise to determine he need to run the existing central-plant simultaneously with the indow units should be carried out. Our calcuations have shown

EXECUTIVE SUMMARY

An energy audit has been conducted by TERI on Shram Shakti Bhavan on behalf of the Department of Power. The objective of the audit was to identify areas where energy consumption could be reduced and recommend steps to initiate energy conservation measures.

During the year 1988, the total electrical energy consumed in Shram Shakti Bhavan was 1003081 kWh*. A physical audit of the energy consuming appliances was carried out. Also, energy consumption was monitored on an hourly basis for a total of four weeks in January and March 1989. Detailed discussions were held with officers in the CPWD as well as the departments/ministries located in Shram Shakti Bhavan.

Based on TERI's audit, some of the major recommendations for reducing electrical energy consumption are listed below, along with the estimated annual energy savings. A detailed list of recommendations is given at the end of the report.

Building Operation Patterns

- Improved housekeeping i.e., making sure all equipment and lights in individual rooms are turned off at nights, offers an annual energy saving potential of 39,000 kWh.
- Discouraging the use of radiant heaters for warming up of lunches could save 11,836 kWh.
- Rewiring of corridor and toilets in order that only half of the corridor lights are switched on at night, and all toilet lights are switched off:

  Assured saving : 36,138 kWh
  Probable saving : 86,317 kWh

Lighting

- Replacing existing poor quality chokes (ballast) with high efficiency chokes for tubelights would save 30,370 kWh
- Alternatively, replacing poor quality chokes (ballasts) with good quality solid state electronic chokes would save 86,050 kWh
- Use of 36W fluorescent tubelights would reduce consumption by about 16,211 kWh.

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* Estimated by apportioning total electricity consumption of Shram Shakti Bhavan and Transport Bhavan in a ratio of 70:30.

that the window units in these rooms have the capacity to effectively cool these rooms independantly.

Our calculations lead us to believe that the NDMC energy meter, which is installed on the incoming side of the high tension feeder supplying power to both Transport Bhavan and Shram Shakti Bhavan, readings are marginally higher (5 per cent).

On our request, the CPWD has kindly agreed to install a separate meter on the LT side for metering consumption of Shram Shakti Bhavan. At the time of finalizing this report, the meter was fixed, but had some mechanical faults. This is currently being rectified. It is suggested that readings are taken on the three meters in order to establish the correct consumption.

It is suggested that an internal task force be constituted to immediately evaluate the recommendations, within a given time frame and draw up a plan of action to initiate suitable measures to reduce energy consumption in Shram Shakti Bhavan.

1.3 Analysis

To evaluate alternative options for lighting, TERI contacted Phillips India, who were extremely helpful. A daylighting computer program developed at IIT Delhi was used to evaluate natural lighting options. Blue Star and Voltas were requested to give their quotations and designs for central air-conditioning. The design outline and quotations of these firms is attached as Annexure II.

Daily and annual electrical consumption patterns were studied, and the observed values were compared against calculations based on the collected data. There were some differences between observed and calculated values and these are discussed in Chapter 2.

Chapter 3 discusses the building's systems for lighting, cooling and heating. Energy conservation options have been identified and listed for each of these systems.

The operation pattern of the building was studied carefully to identify strategies to promote energy conservation. These are discussed in Chapter 4.

Chapter 5 looks at some instrumentation options which will encourage energy conservation and monitoring. Chapter 6 discusses the importance of public awareness to energy conservation. Finally, a prioritized list of recommendations has been included for quick reference.

CHAPTER 1
INTRODUCTION

.1 Why energy audit

In view of the rising costs of electricity supply and the reed to raise large resources to meet the demand, the Department of Power has identified energy conservation as a strategy to reduce the gap between demand and supply. Carrying out energy audit in industries and large commercial complexes would help in identifying areas for reducing energy consumption, with or without additional investments.

In line with this policy, Government of India has decided to initiate energy audits in several government offices. The Department of Power has taken the lead by launching an energy audit in Shram Shakti Bhavan.

A team from TERI visited Shram Shakti Bhavan on 16/11/1988 for a preliminary assessment of the extent of work involved. The project proposal was subsequently developed and submitted to Department of Power. The project was sanctioned on 29/12/1988.

1.2 Data collection

A physical audit of the electrical appliances, lighting systems in all the floors of Shram Shakti Bhavan was carried out by a three man survey team, over a period of 45 days. Data on the number and type of equipments, in different rooms, the condition of lighting systems (clean, dirty), the color of the wall and windows (covered, uncovered), was collected. A summary of the information collected is included in Annexure I at the end of the report.

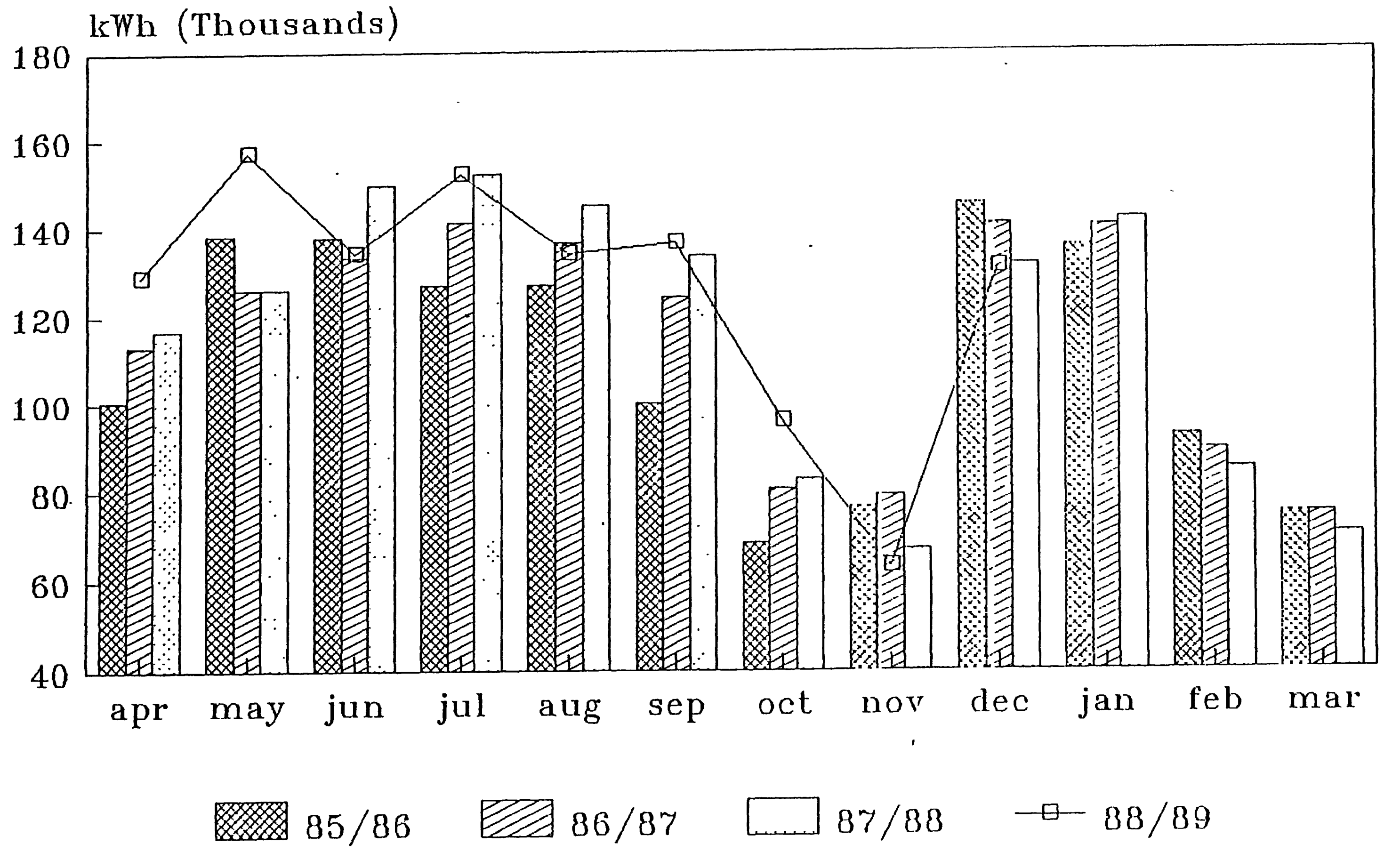
A high quality digital display LICOR luxmeter was used to measure illumination levels in almost every room at the level of the work table. Power factor and instantaneous load measurements were made using a digital, three phase PMT tong tester with integrating facility. Detailed discussions with various service personnel revealed insights into the functioning and maintenance of equipments in the building.

A second two man team worked in two shifts to monitor the energy consumption pattern of the building. This information was collected for two weeks beginning mid January 1989, and for two week in mid-March 1989. Data on monthly energy consumption for the period April 1986 to January 1989 and copies of the building plans were collected from CPWD.

Figure 2.1

HISTORICAL CONSUMPTION PATTERN

SHRAM SHAKTI AND TRANSPORT BHAVAN



adjusted for meter reading dates

CHAPTER 2
ELECTRICAL ENERGY CONSUMPTION PATTERN

2.1 Annual Consumption Pattern

High tension voltage at 11 kV is supplied to the sub-station located behind Shram Shakti Bhavan. An energy meter (henceforth called NDMC meter) is connected across the incoming high tension feeder to monitor the electricity supplied to Transport Bhavan and Shram Shakti Bhavan. A separate low tension three phase energy meter has been connected by the CPWD on the bus bar supplying power to Transport Bhavan (henceforth called TB meter) since October 1988.

Since consumption for Shram Shakti Bhavan was available only from October 1988, the trends in the combined consumption was studied. Fig. 2.1 shows the annual energy consumption pattern of the combined loads of Transport Bhavan and Shram Shakti Bhavan. Since, the meter readings are not always taken on the same day, monthly consumption data given by CPWD was suitably adjusted to account for variations in meter reading dates.

Energy consumption was lowest in March, October and November when fans, coolers and air-conditioners were not used, and the temperatures were not low enough for people to start using heaters. The consumption peaks in May/June/July, the hottest periods in the year. Electricity consumption in 1986-87 increased by 7.87 per cent over consumption in 1985-86, and there was a marginal reduction of 1.7 per cent in consumption in 1987-88. For the period April to December 1988, consumption rose by 3.65 per cent. In 1987-88, the drop in consumption is mainly due to a warmer winter, indicated by a reduced winter consumption.

2.2 Daily Hourly Consumption Pattern

As mentioned earlier, data on hourly loads was collected for two weeks beginning mid-January and another two weeks beginning mid-March.

Fig. 2.2 shows the demand profiles for typical days in January and March. Although the demand is much higher in January (due to large heating load) the shape of the curves for both months is similar.. There are two peaks, one between 12:00 noon and 1:00 p.m., and a second peak around 3:00 p.m. There is a fall in demand around 2:00 p.m.

The first peak between 12:00 noon and 1:00 p.m. may be explained by the fact that heaters are used to warm lunches in individual rooms. This phenomenon is discussed further in Chapter 4 under the section - hotcases. The succeeding fall in demand is probably due to building occupants leaving the building during lunch time to enjoy the winter sun. We note that feature does not occur in March.

Enquiries were made to determine possible reasons for the peak occurring at 3:00 p.m. Discussions revealed that meetings are normally scheduled for afternoons and with this, there is a resultant increase in loads from air-conditioners and lighting in conference rooms. The Ministry of Labour has its dealings with the public in the afternoon, leading to increased usage of the lifts.

2.3 Overall Energy Scenario

Table 2.1 gives the estimated annual energy consumption by end-use for Shram Shakti Bhavan. These calculations are based on a physical count of various kinds of equipment and observed usage patterns. Fig. 2.3 shows the same information in graphic form, while Fig. 2.4 shows the breakup of connected load in the building.

From these figures, it can be seen that the lighting system uses about 33.4 per cent of the total energy consumed by the building. The energy required for cooling is about 28.6 per cent of the total (air-conditioners, desert coolers and fans). Heating accounts for about 15.9 per cent of the annual requirement.

Table 2.1: Annual energy consumption by end use (estimated)

End Use	Units	Percentage
Air-conditioning	1,55,832	16.6
Fans & Coolers	1,12,049	12.0
Heating	1,48,854	15.9
Lighting	3,13,141	33.4
Equipment & Lifts	2,07,096	22.1
Total	9,36,972	100.0

Considering that the cooling season is six months (mid April to mid September) while the heating season is only two months then it is found that:

a. the building uses only 25,972 kWh (or 2.8 per cent of the annual consumption) per month for cooling by 85 air-conditioners, over 200 desert coolers and about 850 fans;

Figure 2.2

DAILY DEMAND PROFILE

SHRAM SHAKTI BHAVAN

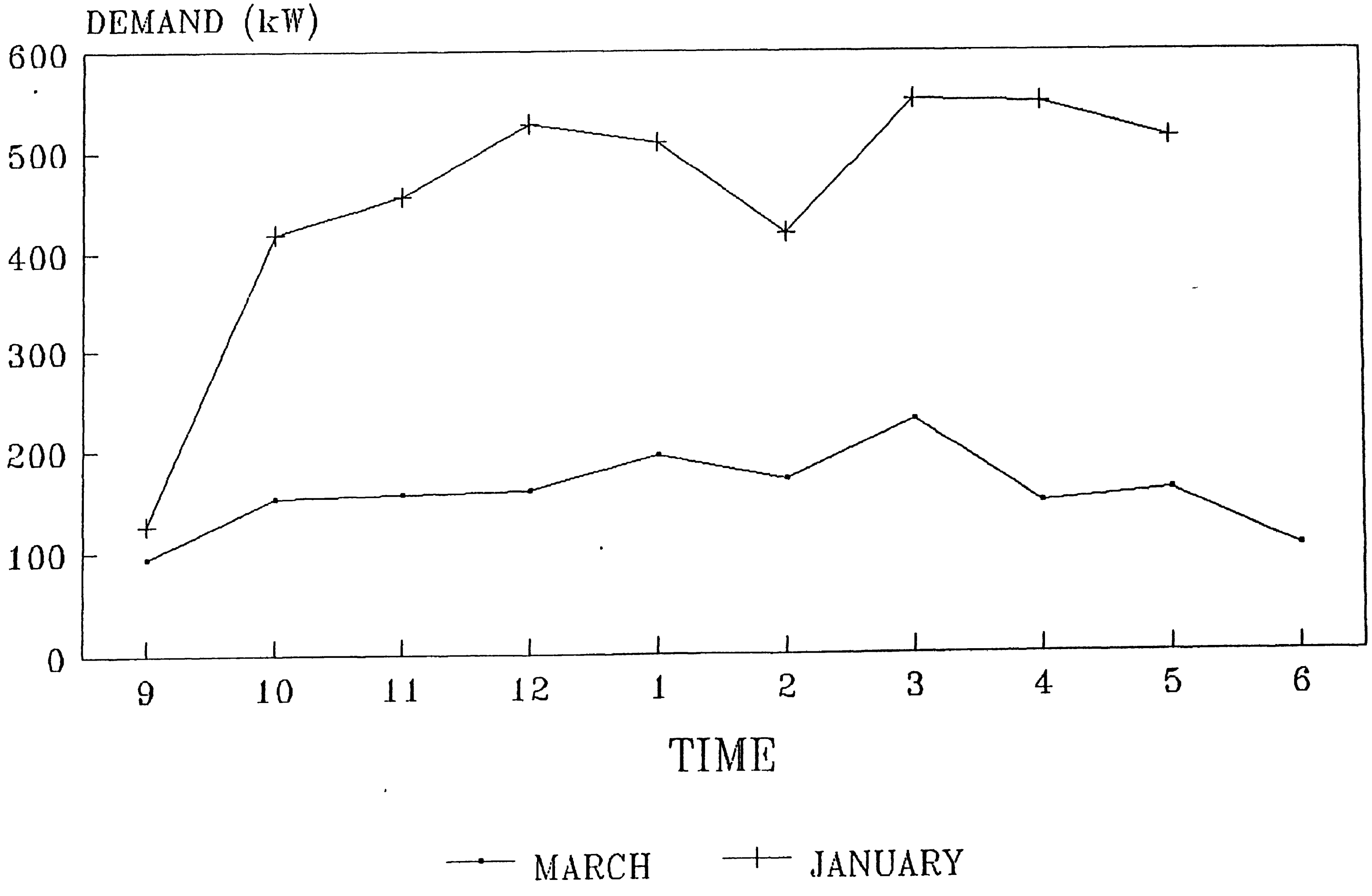
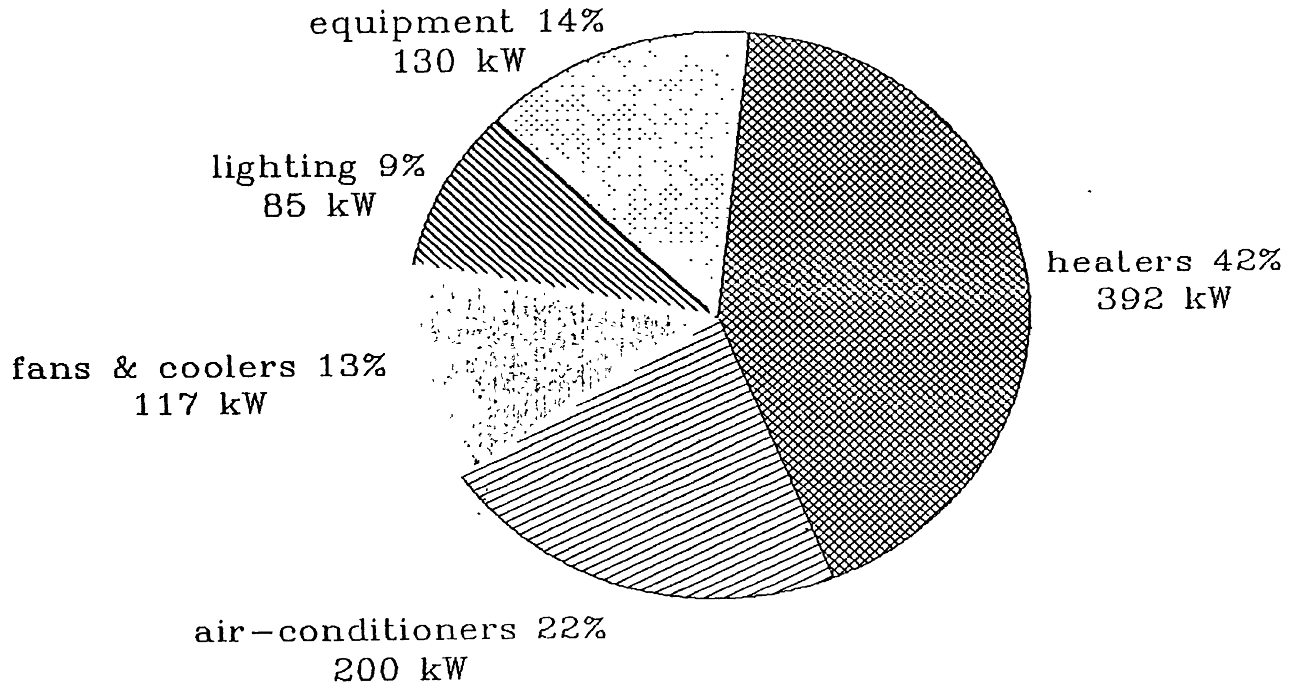


Figure 2.4

CONNECTED LOAD

SHRAM SHAKTI BHAVAN

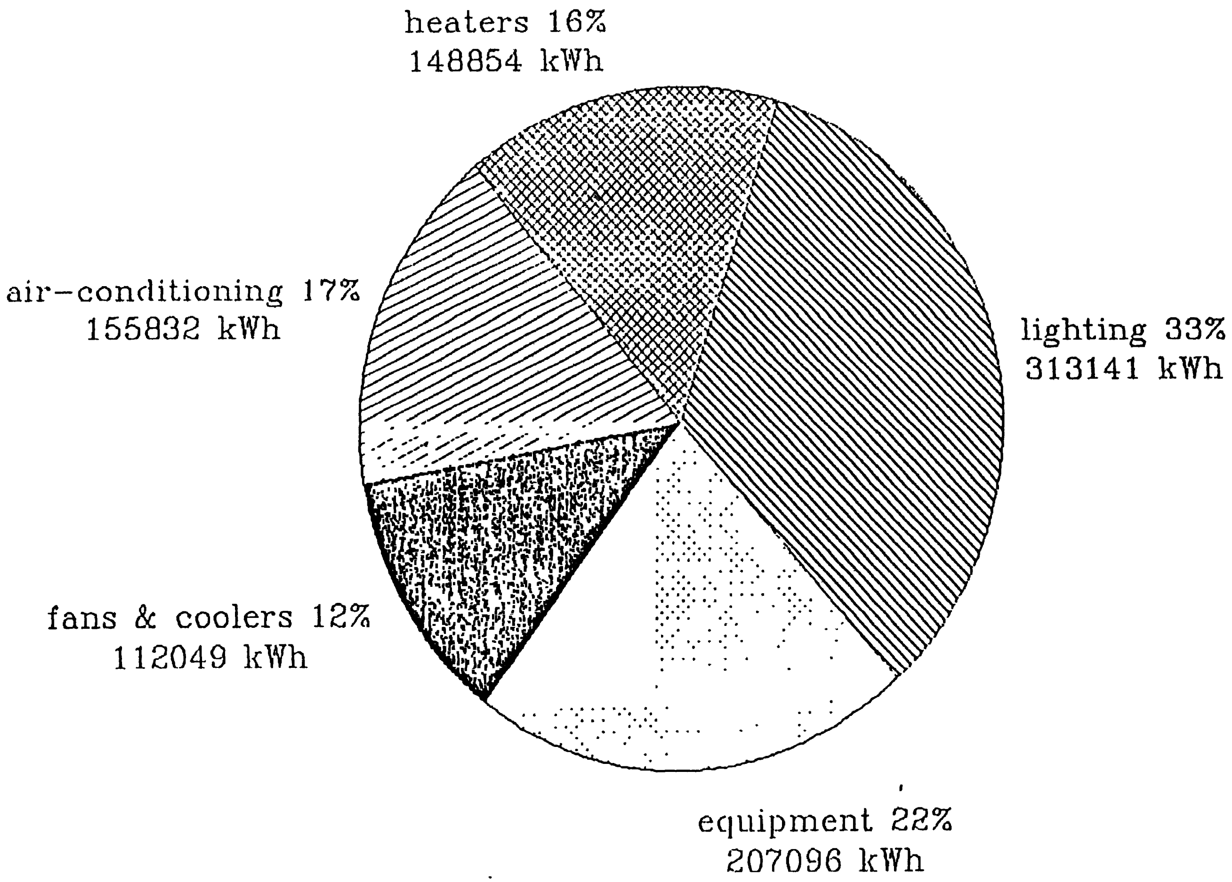


estimated from physical count

Figure 2.3

ANNUAL ELECTRICITY CONSUMPTION

SHRAM SHAKTI BHAVAN



estimated values

Table 2.2 (a): Percentage of energy consumed by Shram Shakti Bhavan before rectification of meter connection (units consumed from 8:00 a.m. to 8:00 p.m.)

Date	Energy as recorded by		Share of TB (%)	Energy Consumed SSB (kWh)	Share of SSB (%)
	NDMC kWh	TB meter kWh			
5/1/89	6506.7	744.0	11.4	5762.7	88.6
6/1/98	5973.3	840.0	14.1	5133.3	85.9
9/1/89	7945.4	816.0	10.3	7129.4	89.7
10/1/89	8040.0	1032.0	12.8	7008.0	87.2
11/1/89	6293.3	1008.0	16.0	5285.3	84.0
12/1/89	7453.3	1056.0	14.2	6397.3	85.8
13/1/89	7220.0	1056.0	14.6	6164.0	85.4
16/1/89	8546.7	888.0	10.4	7658.7	89.6
25/1/89	6826.7	960.0	14.1	5866.7	85.9
27/1/89	6753.3	830.4	12.3	5922.9	87.7
30/1/89	6453.3	1027.2	15.9	5426.1	84.1
31/1/89	6140.0	926.4	15.1	5213.6	84.9
1/2/89	6553.3	796.8	12.2	5756.5	87.8
2/2/89	6266.7	1152.0	18.4	5114.7	81.6
3/2/89	5353.3	676.8	12.6	4676.5	87.4

Table 2.2(b): Percentage of energy consumed by Shram Shakti Bhavan after rectification of meter connection rectified (Units consumed from 8:00 a.m. to 8:00 p.m.).

Date	Energy as recorded by		Share of TB (%)	Energy consumed SSB (kWh)	Share of SSB (%)
	NDMC kWh	TB meter kWh			
6/3/89	2700.0	916.8	34.0	1783.2	66.0
7/3/89	2660.0	840.0	31.6	1820.0	68.4
8/3/89	2466.7	772.8	31.3	1693.9	68.7
9/3/89	2500.0	758.4	30.3	1741.6	69.7
10/3/89	2420.0	696.0	28.8	1724.0	71.2
13/3/89	2540.0	753.6	29.7	1786.4	70.3
14/3/89	2566.7	816.0	31.8	1750.7	68.2
15/3/89	2880.0	763.2	26.5	2116.8	73.5
16/3/89	2580.0	758.4	29.4	1821.6	70.6
17/3/89	2953.3	753.6	25.5	2199.7	74.5
20/3/89	2560.0	763.2	29.8	1796.8	70.2
21/3/89	2413.3	787.2	32.6	1626.1	67.4

b. the building consumes 74,427 kWh per month (or 8 per cent of the annual consumption), for heating by over 300 heaters.

This imbalance in heating and cooling requirements arises from the fact that while almost all rooms get heating in winter, only parts of Shram Shakti Bhavan are air-conditioned.

2.4 Meter Readings

Table 2.2(a) lists the units consumed from 8:00 a.m. to 8:00 p.m. for some days in January '89. It is seen that, at maximum, Transport Bhavan consumed only about 19 per cent of the total energy used by both buildings.

These figures were then checked using estimates for energy consumption based on the connected load for various energy consuming equipment in Shram Shakti Bhavan. Calculations showed that Shram Shakti Bhavan could not consume 81 per cent of the total energy as indicated by the meters. When this was pointed out to the CPWD, they were able to trace an error in the wiring of the Transport Bhavan meter. A new meter has now been correctly installed.

Table 2.2(b) lists units consumed during the same time interval in March '89 after the correction in metering was carried out. The meter now indicates that Shram Shakti Bhavan consumes, on an average, about 70 per cent of the total energy consumption for the two buildings.

This figure of 70 per cent of the combined consumption has been used in our calculations to estimate savings in Shram Shakti Bhavan.

From the information given in Fig.2.1, Shram Shakti Bhavan's annual electrical consumption for 1987/88 works out to be 10,00,384 kWh. This figure is 6.7 per cent greater than the value of 9,36,972 kWh estimated in section 2.3, which was calculated using assumptions meant to overestimate (rather than underestimate) the consumption figures. To check the possibility of the NDMC meter reading high, the CPWD has, on our request, agreed to install a third meter on the LT side of Shram Shakti Bhavan bus bar. The meter had been installed, but developed some mechanical fault which is currently being rectified. It is reccomended that readings of these meters be maintained for a period of at least one month to check the accuracy of the combined meter.

CHAPTER 3
BUILDING OPERATION AND MAINTENANCE

3.1 Electrical System

3.1.1 Observations

During the period that TERI monitored daily demand, the voltmeter on the high tension panel stayed below 9.7 kV. This suggests that either the voltmeter is reading low, or NDMC supply voltage is much lower than the stipulated 11 kV.

The high tension supply is sent to two 750 kVA transformers. One transformer supplies TB and the other supplies Shram Shakti Bhavan. Inside Shram Shakti Bhavan there are distribution points on each floor - three on A-wing, two on B-wing and one in the Annexe (upto third floor). Voltage measurements at distribution points on the second floor indicated the voltages were between 380 V to 397 V, significantly below the ideal 415/440 V.

The building electrical system is poorly maintained. Individual floor loads could not be measured since distribution points on a particular floor were also supplying power to other floors. It was extremely difficult to determine as to which areas were being supplied through which distribution boxes. Some reasons for poor maintenance of the system seem to be:

- Frequent movement of high ranking officials into and out of the building, also, shifting to different locations within the building. Since very short notice is given to the electrical personnel, they then cut corners to hook up the required number of air-conditioners overnight.

- Lack of planned system shut down. Maintenance is normally carried out on Saturday which is a non-working day. If, however, a senior official comes to office, which happens often, power has to be restored to that wing immediately.

TERI's team did not find any MCB (miniature circuit breaker) in any of the distribution boxes inspected. Some of the fuses in the boxes had been replaced by thick wire. Sparking of loose wires was noticed in one of the distribution boxes on the first floor.

Table 3.1. Calculated and measured power factor

Reactive load

p.f. for fluorescent tubes = 0.52
number of fluorescent tubes = 1500
connected load per tube = 0.055 kW
total connected lighting load = 82.5 kW
reactive load = 70.5 kW

Real load

- assume 80 per cent of resistive heaters are at unity p.f.
- neglect inductive loads of convective heaters

Heater Type

	single rod	twin rod	coil
number	206	23	17
load kW	206	46	17

heater load = 0.8 x 269 = 215.2 kW
light load = 82.5 kW
real load = 297.7 kW
calculated p.f. = cos ($\sin^{-1}$ (70.5/297.7))
= 0.955
measured p.f. = 0.96

Table 3.2 Floorwise distribution of heaters

Floor No.	Single rod	Twin rod	Convector	Coil	Tables[+]
0	15	4	2	5	177
1	19	2	10	0	113
2	18	1	18	2	136
3	33	0	15	0	112
4	24	2	24	2	183
5	26	5	7	4	199
6	49	7	5	3	271
Annex	22	2	1	1	127
Total	206	23	82	17	1318

[+] Tables - number of working desks in each floor

3.1.2 Recommendations

Low voltage conditions on motors cause high amperag draw which increases line losses. Loose connections and ba contacts cause increased amperage draw, power loss an heating which make for an inefficient system. Arcing is dangerous fire hazard; as is the absence of MCB's an substitution of fuses with wire.

The electrical system at Shram Shakti Bhavan needs to be thoroughly overhauled. Floor loads must be connected from the appropriate distribution box only. MCB's should be incorporated into each box, and these should be clearly labelled. The CPWD must be allotted a fixed system down time for weekly maintenance. A regular maintenance program needs to be developed and strictly implemented so as to reduce excessive energy losses, increase equipment life and improve the existing hazardous situation.

3.2 Power factor

Power factor is the ratio of real power by apparent power, where apparent power is the vector sum of real power and reactive power. Thus the ideal case is to have a near unity power factor. Indian industry has to pay an extra penalty for a power factor of less than 0.85.

During winter months Shram Shakti Bhavan maintains a high power factor, measured at 0.96. This is attributed to the large fraction of resistive heating load, shown in Table 3.1, when compared to the lighting load.

In summer, the power factor is expected to be much lower since all space cooling equipment are inductive loads.

3.3 Hotcases

The daily demand profile of Shram Shakti Bhavan showed a peak between 12:00 noon and 2:00 p.m., as shown in Fig.2.2. This peak is probably due to the building occupants heating up thei lunch on radiant and coil type heaters. Table 3.2 shows the distribution of heaters and the approximate number of occupants on each floor, which was determined by counting the number of work desks on each floor.

Radiant heaters are turned upwards so the front grill is in a horizontal position and the lunch boxes are placed on top of the grills. Food particles dropping onto the mirrored surface reduce the the effectiveness of the heater. In many rooms visited, there were radiant heaters which did not give out any appreciable heat if a person was more than a meter away, because the mirrored surface was black with burnt food particles.

The main lobby on the ground floor has very good daylighting, and does not need artificial lights during daytime. The TERI team switched off the lobby lights on one of our visits, and we found that these continued to be off, on our subsequent visits.

Staircase lights are not needed during the daytime, and should be switched off.

3.5 Overnights

Table 3.4(a) shows the energy consumption in kWh between 8:00 p.m. and 8:00 a.m. as indicated by the NDMC meter and the correctly wired TB meter. Column four titled SSB shows the difference i.e. energy consumed by Shram Shakti Bhavan.

Table 3.4(a): Overnight energy consumption at Shram Shakti Bhavan

Overnight readings for 12 hrs, taken between 8.00 pm and 8.00 pm

DATE	NDMC kWh	TB kWh	SSB kWh
6-7/3	386.7	33.6	353.1
7-8/3	313.3	43.2	270.1
9-10/3	360.0	38.4	321.6
13-14/3	400.0	38.4	361.6
14-15/3	400.0	76.8	323.2
		average	325.9

Existing system

equipment	no.	rating kW	load	units
corridor,FLT	120	0.055	6.6	79.2
toilets,FLT	57	0.055	3.1	37.6
exterior,INC	30	0.060	1.8	21.6
minimum overnight energy consumption				138.4

Probable energy savings from better housekeeping (4 nights, Mon-Thu for 52 weeks) = 39,004 kWh

Cost of energy saved = Rs.58,500

In Table 3.3 we have conservatively estimated that the energy used for heating lunches in this manner as 11,836 kWh at a cost of Rs.17,754 annually. This calculation assumes that each heater is used for four months in a year for only 30 minutes per day. Since many rooms share a single heater between 3 to 5 people, this is a conservative assumption.

Hot cases to handle 200 lunch boxes per floor, will reduce peak demand, save energy and stop degradation of the radiant heater surfaces. It is also recommended that after the hot cases are installed the use of heaters should be discouraged during non-winter months.

Table 3.3. Estimated annual energy consumption by heaters for warming lunch

type of heater	number of heaters	hrs	load (kW)	yr	units consumed
coil	17	0.50	1	88	748
single rod	206	0.50	1	88	9064
twin rod	23	0.50	2	88	2024
energy used		=			11836 kWh
energy cost (@ Rs. 1.5/unit)		=		Rs.	17754

An innovative hotcase we have seen in a Delhi office consists of a plywood box with one 100W bulb. This simple hotcase is able to keep 50 lunches piping hot. We suggest a wooden case with one inch of fibre glass insulation all around and having a shelf space of one square meter (estimated cost Rs.600) with two 60W bulbs. Five such boxes per floor will be sufficient for Shram Shakti Bhavan. Total cost for these hot boxes is estimated at Rs.21,000. If used for two hours every day for four months, the hot boxes would consume about 739 kWh. The simple payback works out to about 1.2 yrs.

3.4 During Office Hours

There are 3 pairs of toilets (ladies and gents) on each floor, having a total of 57 tubelights. A couple of toilets are presently being used as store rooms. The toilets located on A and B wings have good daylighting and although they do not require artificial lighting during the day, all the tubelights that were not burned out were kept on. Some of the toilets did not even have switches to shut off the tubelights which were left on round the clock. Switching off half these lights during office hours, would save 3,724 kWh or Rs. 5,587 annually.

3.6 Weekends

Table 3.5 gives the number of units consumed between 8:00 p.m. on Friday, and 8:00 a.m. on Monday as shown by NDMC and TB meter readings. The fourth column, titled SSB represents the difference, indicating energy consumption by Shram Shakti Bhavan.

Since it is difficult to model the use of the building accurately for Saturdays when some officials may come to work, the minimum possible energy consumption with the existing use patterns was determined. Toilet and corridor lights were assumed to be on for 24 hours and external lights on for 9 hours every night for 3 nights (Fri, Sat, Sun). This worked out to 633 kWh, and is the weekend consumption possible if the building is perfectly managed, and no one comes to work on Saturdays and Sundays.

The assured energy saving potential is now identified by making the computations for the modified system, i.e., 60 corridor lights and no toilet lights for the same conditions as above. This works out to 247 kWh per weekend, i.e., an annual savings of 20,077 kWh or Rs. 30,116. This is the saving that would be assured, if the building was perfectly managed before and after system modification. The actual savings that can be realized is much higher, since the building is not perfectly managed at present. This saving could be much higher, as high as 86,317 kWh or Rs.1,29,476 annually (Table 3.5) if the building is well managed over weekends.

Enquiries from two wiring contractors suggested a cost of Rs.50 per meter for wiring up alternate corridor lights together. This worked out to approximately Rs.49,000 for all seven floors. Since the assured savings are Rs.54,207 annually, the payback works out to be approximately 11 months.

A visit to Shram Shakti Bhavan at night showed that all the corridor and toilet lights were indeed switched on. Since we are not aware of any equipment that needs to remain on during night hours, the minimum overnight consumption was calculated to be 138.4 kWh as shown in Table 3.4(a). This indicates that it is possible to save about 187.5 kWh each night by making sure that all lights, equipment, heaters or air-conditioners are switched off at the end of the day. This works out to a probable energy saving of about 39,000 kWh.

During our visit, we found that the illumination level were higher than the recommended value of 70 lux (Table 4.1) in corridors. Each corridor has six to seven tubelights controlled by two switches, one at each end. Thus each switch controls three (sometimes four) tubelights. If only half the corridor tubelights and none of the toilet tubelights are used at night, then the overnight consumption will reduce to 61.2 kWh as shown in Table 3.4(b).

Table 3.4(b) Assured energy savings - overnights

Modified system

equipment	no.	rating kW	load	units
corridor,FLT	60	0.055	3.3	39.6
toilets,FLT	0	0.055	0.0	0.0
exterior,INC	30	0.060	1.8	21.6
minimum overnight energy consumption				61.2

Assured energy saving based on 4 working days for 52 weeks		16061.76 kWh
cost of energy saved	Rs.	24092.64

One way of calculating at the energy saving that is possible by this measure is to calculate the minimum assured energy savings that is possible. Assuming that the existing lighting system in the building is managed perfectly (is kept on from 8:00 p.m. to 8:00 a.m.) and no other equipment is used, at least 138.4 kWh will be used. Under the same conditions, the modified system (only 60 corridor lights and no toilet lights) will use only 61.2 kWh as calculated earlier. This translates into an assured annual energy savings of 16,061 kWh or Rs.24,093.

This kind of selective switching can be done by manually switching off half the tubelights by existing switches. This method would mean no investments, but would cause non-uniform light levels in the corridors.

Table 3.6: Energy conservation by modifying the building's operation and maintenance

Recommendation	Reduction in annual energy consumption		Estimated investment	Approximate payback period
	kWh	Rs.	Rs.	Yrs.
No Cost Measures				
1. Switching off tubelights in toilets, main lobby and staircases during daytime	3,724	5,587	Nil	NA
2. Improved overnight housekeeping; making sure all equipment, lights etc. in rooms are switched off by 8.00 p.m. every evening	39,000	58,500	Nil	NA
Low and medium cost measures				
3. Hot cases	11,836	17,754	21,000	1.18
4. Rewiring alternate lights on corridors to one control switch			49,000	0.92 based on assured saving
a) Overnight savings				
assured saving	16,062	24,093		
b) Weekend saving				
assured saving	20,077	30,116		
probable saving	86,317	1,29,476		
ther measures				
Reconditioning of electrical system				

Table 3.5: Weekend energy consumption at Shram Shakti Bhavan

DATE.	NDMC kWh	TB kWh	SSB kWh
10-13/3	2186.7	254.4	1932.3
17-20/3	2020.0	139.2	1880.8
		average	1906.6

Existing system

equipment	no.	rating kW	load kW	units
corridor,FLT	120	0.055	6.6	396.0
toilets,FLT	57	0.055	3.1	188.1
exterior,INC	30	0.060	1.8	48.6
minimum weekend energy consumption				632.7

Modified system

equipment	no.	rating kW	load kW	units
corridor,FLT	60	0.055	3.3	198.0
toilets,FLT	0	0.055	0.0	0.0
exterior,INC	30	0.060	1.8	48.6
minimum weekend energy consumption				246.6

assured energy saving	20077.2 kWh
cost of energy saved	Rs. 30115.8
probable energy saving	86317.4 kWh
cost of energy saved	Rs.129476.1

cabins, which only worsens the situation. Light levels as low as 45 lux were measured in these rooms. Annexure IV is an optimized design by Phillips India for a typical section hall. This design recommends use of six high efficiency twin lamp fixtures with mirror optics to give an illumination level of 259 lux.

Table 4.1 Recommended values of illumination

Sl. No.	Visual Tasks	Illumination lux
1.	Libraries:	
	a) Shelves (stacks)	70-150
	b) Reading rooms (newspapers and magazines)	150-300
	c) Reading tables	300-700
	d) Book repair and binding	300-700
	e) Cataloguing, sorting and stock rooms	150-300
2.	Offices:	
	a) Entrance halls and reception areas	150
	b) Conference rooms and executive offices	300
	c) General offices	300
	d) Business machine operation	450
	e) Drawing offices	
	1) General	300
	2) Boards and tracing	450
	f) Corridors and lift cars	70
	g) Stairs	100
	h) Lift landings	150
	i) Telephone exchanges:	
	1) Manual exchange rooms (on desk)	200
	2) Main distribution frameroom	150

Taken from Part VIII Building Services - Section 1 Lighting and Ventilation

Inadequate lighting causes energy wastage. Since he does not have enough illumination on his workdesk, the occupant switches on neighbouring lights as well. These extra lights use up electrical energy without giving illumination at the required location. Inadequate lighting also causes tiredness and loss of productivity.

It is recommended that qualified lighting designers be given the task of providing adequate levels of illumination in the room types mentioned above. One or two sample rooms should be fitted with high quality illumination systems, which could then be extended to other parts of the building.

CHAPTER 4
ENERGY CONSERVING OPTIONS IN LIGHTING, COOLING AND HEATING

4.1 Lighting System

The survey team checked light levels at table top height for almost 95 per cent of the rooms in Shram Shakti Bhavan. The number of light points, condition of fixture and lamp were also recorded. Annexure I lists a summary of the findings of the survey team.

4.1.1 Room Light Levels

Rooms facing east are occupied by very senior government servants e.g., Ministers and Secretaries of various Departments, specially on the second and fourth floors. Generally these rooms are air-conditioned. Curtains or venetian blinds block out direct sunlight as well as natural light, and artificial lights are used throughout the day. The few incandescent lamps used in the building were mainly found in these rooms. Measured light levels were found to be near about 250 lux, against a prescribed level of 300 lux for general office work. Table 4.1 is an extract from the National Building Code and shows recommended lighting levels for office spaces.

Rooms facing west are long and narrow. On the second floor, a portion leading out to the corridor is usually partitioned and occupied by personal staff of ministers and department secretaries. The remaining portion of the room is occupied by officers of the rank of Joint Secretary. Illumination levels in these rooms are similar to the west facing rooms. Windows are mostly covered by curtains and Venetian blinds.

Administrative officers of the rank of Directors, Deputy Secretary and others occupy the south facing rooms. These rooms enjoy the maximum amount of natural light (daylighting), having well over 300 lux during daytime in most cases. Typically these rooms have two single tube fluorescent lamps on open 'putti' fixtures which cannot maintain the required level of 300 lux during night time. Annexure III is a design calculation for these types of rooms by Phillips India to determine the illumination levels provided by the existing lighting system without daylighting. The calculated illumination level works out to an average of 184 lux.

Most rooms on the north facing side of the building are section halls. The lighting levels are far from adequate in many of these long, narrow (11.8m x 4.1 m) rooms having three to five single tube fluorescent lamps on putti fixtures. Many of these rooms are partitioned into smaller corridor has diffuse acrylic luminaires mounted on the walls. Acrylic diffusers are very inefficient as they absorb about 40 per cent of light.

The lamp and luminaire must be cleaned every six months. All three ministries employ odd-job persons who come in early to clean the rooms. They can be taught to maintain fixtures on a regular schedule coordinated by the respective Section Officer. This will result in higher levels of illumination for the same amount of installed lighting, which will lead to increased productivity and high morale of staff.

..2.3 Relamping

A fluorescent lamp should be replaced when its lumen output has depreciated below the design value for providing adequate illumination. New lighting systems are being designed taking into account group relamping at 70 per cent of burning life (3500 hours), by which time the lamp output has fallen by 30 per cent. This fall in output is known as lamp lumen depreciation (LLD).

In a typical office situation, the economic life of a lamp is 3500 hours since after this period of time, the extra investment in additional light points to maintain the illumination level becomes very high.

Replacing 40 W tubes with the 36 W tubes in Shram Shakti Bhavan with the existing use patterns would result in an energy saving of about 15,088 kWh per year or Rs. 22,632, assuming that presently only 20 per cent of the existing tubes are the slimline variety. This assumption is based on the survey team's observations. Replacing all 40 W tubelights with 36 W tubelights @ Rs.30 per tubelight will cost Rs.36,000, i.e. a simple payback period of just over one and a half years. The calculations are shown in Table 4.2.

To maintain design levels of illumination, lamps must be replaced at the end of their economic life. For Shram Shakti Bhavan, fluorescent tubes should be replaced (by 36 W slimline tubes) about every 17 to 18 months to retain design illumination levels. Since there are 14 wings in the building (seven floors having A and B wings), plus three floors of Annexe, the building may be logically separated into these 17 sections for relamping. Each month one section should be relamped completely. Regular maintenance and relamping programs will enhance the quality and life of the lighting system.

In a government organization there could always be awkward questions asked regarding the fate of the tubelights which are removed as part of the regular group

4.1.2 Energy Conservation Opportunities in Lighting

4.1.2.1 Enhancing Natural Lighting

Controlled daylight is the most efficient source of illumination giving about 220 lumens per watt. In comparison, low pressure sodium vapour lamps, one of the most efficient sources of artificial light, produces about 185 lumens per watt of monochromatic light. That is, in summer it is energy efficient to allow the correct amount of daylight into the room, than to completely draw the curtains and switch on artificial lights.

Dirty windows reduce the amount of natural light entering the rooms and consequently decrease the illumination levels inside rooms. The windows on the north side of Shram Shakti Bhavan require to be cleaned since they are dirty and have paint streaks on the outside surfaces.

In Shram Shakti Bhavan, almost every room has a thin window strip (or daylight shelf), above the main window. This daylight shelf has an inclined overhang (chajja) to cut off direct sunshine. It was found that in almost every room in the building, the daylight shelf was dirty or had been made opaque in some manner; either by painting, covering up by dark paper, or physically blocking it up.

Exposing this daylight shelf located above the main window area will increase illumination levels during the daytime. The effects of exposing the daylight shelf are shown in Figs. 4.1 and 4.2 for the four types of rooms discussed above. Lux levels increase by about 50 lux at a distance of two to four meters into the room from the window. This increase can make the difference between inadequate and adequate lighting in many cases. The figures indicate that, where possible, the best seating arrangement would be about two meters in front of the window and facing away from it. The east facing rooms (Minister's rooms) benefit the most from daylighting as they are shallow and have long daylight shelves. Curtains should be made such as to cover the main window but leave the daylight shelf exposed.

4.1.2.2 Fixture Maintenance

Illumination levels can drop below 70 per cent of the design value without regular fixture maintenance. Almost all fixtures on all floors except second and fourth are of the open `putti' type. On the second and fourth floor there are egg-crate fixtures and fixtures set into false ceilings of the room. The second floor

Table 4.3 shows that a annual energy saving of 28,264 kWh or Rs. 42,396 is possible in Shram Shakti Bhavan with the existing use patterns. For this calculation choke losses in poor and good quality chokes were taken as 18 W and 12 W respectively.

At Rs. 65 per good quality choke, the cost of replacing all the chokes at Shram Shakti Bhavan (assuming 100 per cent of installed chokes to be poor quality) works out to Rs.97,500 indicating a simple payback period of about two years and four months.

4.1.2.5 Electronic Chokes

High frequency electronic ballasts (chokes) are now becoming available in the Indian market. Table 4.4 gives a comparison between the conventional choke and the electronic choke. Table 4.5 shows the potential energy savings for Shram Shakti Bhavan by using electronic chokes when compared to poor quality chokes.

Table 4.3 Annual energy saving potential with high efficiency chokes

Assuming 18 W as the loss from a poor quality choke

	choke loss, W	no.	hrs/day	days/yr	kWh
rooms	18	1330	9	264	56881.4
corridor	18	120	24	365	18921.6
toilets	18	57	24	365	8987.8

annual energy consumption = 84,790.8 kWh/yr

Compare with 12 W loss by a high quality choke

	choke loss, W	no.	hrs/day	days/yr	kWh
rooms	12	1330	9	264	37920.9
corridor	12	120	24	365	12614.4
toilets	12	57	24	365	5991.8

annual energy consumption = 56,527.2 kWh/yr

Annual energy saving = 28,263.6 kWh
Cost of saved energy = Rs. 42,395.5

Cost of replacing chokes @ Rs.65 per unit = Rs.97,500
Simple payback = 2.29 yrs or 28 months.

relamping. Such a problem does exist and an acceptable solution must be found after discussion with CPWD and officials in the three ministries. Since the corridor tubelights are used on a 24 hour basis, they will fuse after six months of use. Some of the removed tubelights that still work should be used for replacing the corridor tubelights. These tubelights can also be for replacing fused tubelights between scheduled group replacement.

Table 4.2: Annual energy saving potential by using 36W fluorescent tubes

Assuming 80% of tubelights are of 40 W rating

	wattage	no.	hrs/day	days/yr	kWh
rooms	40	1064	9	264	101122.6
corridor	40	96	24	365	33638.4
toilets	40	46	24	365	16118.4
				total	150,879.4 kWh/yr

Changing over to 36 W tubelights

	wattage	no.	hrs/day	days/yr	kWh
rooms	36	1064	9	264	91010.3
corridor	36	96	24	365	30274.56
toilets	36	46	24	365	14506.56
				total	135,791.4 kWh/yr

Annual energy saving = 15,087.9 kWh
Cost of energy saved = Rs. 22,631.9

Cost of replacing tubelights @ Rs.30 per piece = Rs. 36,000
Simple payback = 19 months

4.1.2.4 High Efficiency Chokes

Presently, chokes (also called ballasts) are supplied to CPWD by the DGTD who buy these items in bulk. Selection criteria are based on lowest cost, and not on energy efficiency. Losses in good quality chokes should not exceed 12 W, while low quality chokes losses can be greater than 20 W.

Table 4.5 Annual energy saving potential with electronic chokes

	choke loss, W	no.	hrs/day	days/yr	kWh
rooms	1	1330	9	264	3160.1
corridor	1	120	24	365	1051.2
toilets	1	57	24	365	499.3
			total	4,710.6 kWh/yr	

Energy saving over poor quality choke = 80,079.4 kWh/yr
= Rs. 120,119.1

Cost of replacing chokes @ Rs. 180 per unit = Rs.216,000
Simple payback = 1.8 yr = 22 months.

This is a new and exciting technology in the Indian market with a payback period of about two years for typical office applications. These products have just come out in the Indian market and some doubts exist about the quality of construction. Poor quality seems to be due to the use of cheap electronic components to keep costs down. There is at least one Indian manufacturer who provides a 2 year guarantee on his products.

We recommend that the CPWD install a few electronic chokes (of different makes) and monitor their performance for reliability before taking a decision for their use. A performance guarantee from the supplier is essential.

It is recommended that only good quality chokes (high efficiency or electronic) are used for replacement of failed items and additional fixtures.

1.2.6 High Efficiency Fixtures

The majority of fixtures installed at Shram Shakti Bhavan are the simple putti type. Light output is not directed downwards where it is needed, instead a lot of light is lost to the ceiling and walls. To improve illumination levels without increasing energy consumption, high efficiency mirror luminaires should be used at selected locations. The design in Annexure IV uses these fixtures.

Table 4.4 : Comparison between Conventional and Electronic Choke

S. No.	Specification	Conventional Choke Good Quality	Electronic-Solid State Ballast
1.	Power consumed in Ballast	12 Watts (app.)	1 Watt
2.	Current consumption of total fixture	300 mA (app.)	115 mA (app.)
3.	Range of operational voltage	190V to 260V	110V to 300 V
4.	Power factor	Around 0.55	Near unity
5.	Functioning of Tube		
	- Light output	2500 lumens	2600 lumens
	- Starting	Delayed	Less than 1 sec.
	- Flickering	Possible	Stabilized output
	- Operating temperature	Will not operate at low temperature	Suitable for varied ambient temperature
6.	Noise Level	Possible	Nil
7.	Starter	Necessary	Not Necessary
8.	Condenser provision	Necessary for power factor improvement	Not required
9.	Choke temperature	Around 55°C	Ambient
10.	Weight	660 grams	130 grams
11.	Light efficiency (Luminosity)	45 lumens/watt	92 lumens/watt
12.	Input power	Only AC	AC or DC

Table 4.7: Energy conservation options in lighting

Recommendations	Saving		Investment	Payback
	kWh	Rs.	kWh	Yr
Replace existing incandescent lamps with compact fluorescent lamps	5,498	8,247	7,800	0.95
Replace existing 40W fluorescent tubes with 36W slinline type	15,088	22,632	36,000	1.6
Replace existing poor quality chokes with high efficiency chokes	28,264	42,396	97,500	2.3
or				
Replace existing poor quality chokes with good quality electronic chokes	80,079	1,20,119	2,16,000	1.8
Other measures				
- clean fixtures every six months				
- enhance natural lighting by cleaning windows, daylight shelf				
- maintain illumination level by following a regular relamping scheme				

4.1.2.7 Compact Fluorescent Lamps

Compact fluorescent lamps, called PL lamps, have very recently been introduced into the Indian market by Philips India. These lamps are aimed as substitutes for incandescent lamps and have the same lumen package (700 to 1600 lumens). They are very efficient light sources and deliver about 85 lumens per watt with very good colour rendering. They are made in 7, 9, 11 and 13 W size and are meant to replace 60W to 100W incandescent lamps.

The majority of lamps in Shram Shakti Bhavan are fluorescent tubelights, but there are about 26 incandescent in two rooms in the A-wing of the second floor. These could be replaced by compact fluorescent lamps, and would save 5,498 kWh annually, (assuming 9 hrs per day burning period). Compact fluorescent lamps have a life of 5000 hr compared to 1000 for an incandescent bulb. Without considering the lamp replacement cost for incandescent bulbs, the payback period for a change from incandescents to compact fluorescent would still be 11 months. The calculations are shown in Table 4.6.

Compact fluorescent lamps are extremely efficient and should be promoted in all feasible locations.

Table 4.6: Energy saving potential of compact fluorescent lamps

Lamp	Rating (W)	hr/d	d/mth	mth/y	kWh
Incandescent	100	9	22	12	6177.6
Compact fluorescent	9+2*	9	22	12	679.5
Energy saved					5,498.1 kWh
Cost of energy saved					Rs. 8,249.15
Investment cost (@ Rs. 300 per piece)					Rs. 7,800.00
Payback period					0.95 yrs.

* Ballast & control gear losses

From Table 4.8, it can be seen that the average hourly electricity consumption varies from 1.07 kWh to 2.83 kWh for 1.5 ton air-conditioners. The power consumption is dependent on condition of filter, thermostat setting, age of air-conditioner condition, size and orientation of room, window area, ambient temperature, humidity and other factors (these factors also account for the lower consumption in an air-conditioner with no filter compared to that in an air-conditioner with a clean filter). In the following estimations, some of these factors have been assumed constant and cooling capacity of individual air-conditioner units has been taken as 1.5 tons.

4.2.2. Dirty Filters

An air-conditioner of 1.5 ton has a power rating of approximately 2.5 kW. According to manufacturers, a correctly sized window air-conditioner has its compressor running 1/3 of the time. Since the fan draws about 200W, the total consumption per hour, of a correctly sized and well maintained air-conditioner, works out to be approximately 1.03 kWh. This is reflected in the first measurement shown in Table 4.8. The measurements was made in April and May.

If the filter is dirty, less amount of return air passes over heat exchange coils and the cooling effect is lowered. The room occupant's reaction is to switch the fan position to "High Cool"(increasing fan speed), as well as turn the thermostat to a lower temperature setting. This causes the compressor to run longer and the fan also draws higher current at the higher speed.

Even if the settings on the air-conditioner were not changed, the lowering of air flow over the evaporator coil would result in the compressor running for longer periods since the refrigerant would remain in gaseous condition for longer periods.

The compressor on an air-conditioner with a dirty filter would run for at least, an additional 10 per cent of the time, and the consumption would be 1.13 kWh as opposed to 1.03 kWh. Forty five air-conditioners in the building (67 per cent of the total number in Shram Shakti Bhavan) have filters which are dirty or clogged. Therefore an extra 918 kWh would be consumed every month in these air-conditioners*.

If the fan speed is increased to compensate for the lower cooling effect, then the consumption increases to 1.78 kWh (the fan consumes approximately 250W instead of

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* assuming that air-conditioners operate for 9 hours per day for 22 days per month.

4.2 Air-conditioning system

In Shram Shakti Bhavan, air-conditioning accounts for about 16.6 per cent of the total electricity consumption (as shown in section 2.3) and constitutes 21.7 per cent of the connected load. In monetary terms, electricity consumption in air-conditioners is estimated to have accounted for approximately Rs. 2.33 lakh in 1987-88. Since any reduction in the electricity consumption effected in the air-conditioning system would lead to significant saving in monetary terms, efforts were made to identify energy conservation options for this system. The following sections deal with some of the measures which could be taken to reduce electricity consumption in air-conditioners.

To study and analyze the performance of air-conditioners, an audit of air-conditioners installed in Shram Shakti Bhavan was conducted. As part of the study, details relating to number of air-conditioners, their rating, etc. were collected. In addition, other performance indicators like condition of filter, functioning of thermostat, etc. were also noted for a sample of the total number of air-conditioners.

It was found from the survey that there are 85 air-conditioners installed in Shram Shakti Bhavan, and a visual inspection of 57 of these showed that 45 air-conditioners had filters which were dirty or clogged and four air-conditioners had significant gaps in their installation (inadequate insulation). Measurements were taken on seven air-conditioners, and the results from the analysis are summarized on Table 4.8.

Table 4.8: Performance measurement on air-conditioner's at Shram Shakti Bhavan

Sl. No.	Cooling capacity (tons)	Average hourly consumption (kWh)	Ambient temperature (°C)	Room temperature (°C)	Remarks
1.	1.5	1.07	35	24	clean filter thermostat working
2.	1.5	2.02	35	23	dirty filter thermostat not working
3.	1.5	2.70	43	30	dirty filter
4.	1.5	2.80	43	25	clean filter
5.	1.5	2.43	43	25	no filter, poor power factor
6.	1.0	1.85	43	31	no filter
7.	1.5	2.80	24	24	no coolant

Based on the above table we recommend that the thermostats be caliberated and the 25°C position be clearly labelled. Cooling the room to this value would represent the optimum balance between human comfort and energy conservation.

To illustrate the importance of thermostatic control, one of the rooms in Wing-A of the second floor, may be considered. The room has an area of 67.2 square meters (12 m by 5.6 m) and has large east facing windows. In summer, when the outside temperature is 43°C, and the internal temperature is to be maintained at 25°C, the room represents a cooling load of 2.35 tons[*] using the ASHRAE cooling load calculation method. Assuming that the room has a single occupant with all lights and windows do not have solar film.

If the room is to be cooled to 24°C, the cooling load offered by some room would increase to 2.68 tons, an increase of approximately 14 per cent.

It is recommended that thermometers be installed near the occupants table, in air-conditioned rooms, and public awareness be created so that individuals contribute to an energy conservation drive by monitoring their respective room temperature and adjusting thermostats to maintain their rooms at 25°C.

4.2.5 Non-operative thermostats

When the thermostat on an air-conditioner does not work, the hourly consumption increases to over 2 kWh, since the compressor operates continuously (as can be seen from Table 4.8). This represents an additional consumption of over 1152 kWh per cooling season for every air-conditioner with a non-operative thermostat. Of the seven air-conditioners' tested, two had thermostats which did not function.

The thermostats of all air-conditioners must be checked before the cooling season each year. The importance of prompt complaint registration for repair of thermostats must be brought to the notice of the room occupants.

4.2.6 Coolant Leakage

It seems that the coolant has leaked out in at least one air-conditioner (telephone exchange) in Shram Shakti

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[*] assuming that air-conditioners operate for 9 hours per day for 22 days per month.

200W). The additional monthly consumption in 45 air-conditioners would be 1,337 kWh[*].

The consumption would be higher for the months of May, through July when air-conditioning loads increase due to harsher climatic conditions. Therefore, simply cleaning the filters on the air-conditioners could result in an annual savings of 5,508 kWh to 8,022[+] kWh.

It is recommended that filters be cleaned at least once a month. This could be made a mandatory part of the existing air-conditioner maintenance contract.

4.2.3 No Filters

Two of the seven air-conditioners tested did not have filters. The absence of a filter results in clogging up of the evaporator heat transfer area with dust. This will greatly reduce heat transfer, resulting in ineffective cooling. This in turn will mean that the compressor will work continuously, increasing the energy consumption. This would also reduce the life of the compressor.

4.2.4 Thermostat Control

The thermostat fitted on most window type air-conditioners is graduated on a scale of 1 to 10, where 10 is the coolest position. The temperature range of the thermostat corresponds roughly between 18°C to 25°C. For tropical summer conditions, Sharma (1977)[@] has evolved the Tropical Summer Index (TSI) and his results are summarized in Table 4.9.

Table 4.9: Tropical summer index

Thermal Sensation	Range (°C)	Optimum
Slightly cool	19 - 25	22
Comfortable	25 - 30	27.5
Slightly warm	30 - 34	32

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[*] assuming that air-conditioners operate for 9 hours per day for 22 days per month.

[+] assuming air-conditioners operate for 6 months in a year.

[@] Sharma M.R., A study of thermal effects of climate and building on human comfort with special reference to India, Ph.D. thesis, Agra University, 1977.

It can therefore be seen that 30 tons of air-conditioning is being used for rooms which have already been provided with adequate number of room air-conditioners.

These rooms are normally not occupied throughout the day and therefore do not require cooling at all times of the day. In fact, in five of the rooms we found peons stretched out on sofa's or carpet enjoying a 'cool' snooze, with the window air-conditioners switched on, in addition to the central air-conditioning.

Assuming the compressors run 5/6 of the time, in 6 months of approximately 12 hrs running per day, the central plant will consume about 41,712 kWh. During winter (2 months) the central plant would consume about 8,831 kWh running 9 hrs/day. In the remaining four months, the blowers would draw about 2,954 running 9 hrs/day. The annual energy consumption by this plant comes to about 53,497 kWh.

In summer, the central air-conditioning plant is not required for air-conditioning the room since all of the six rooms inspected had sufficient installed cooling capacity in the form of window air-conditioning units. Since none of the rooms have sealed windows, there is no requirement for forced ventilation during the milder seasons. In winter, two convectors will be sufficient for each room and will use only 7603 kWh for the entire winter working 9 hrs per day for 2 months. Alternately, the existing window units could have a heater installed.

Shutting down the central air-conditioner plant will result in a saving of about 44,623 kWh after accounting for the energy consumption of one extra window air-conditioning unit and eight convective heaters. In the light of the estimates given above, we recommend that the role of the central air-conditioning plant be re-evaluated from an energy conservation point of view.

4.2.8 Evaluation of Central Air-conditioning for Shram Shakti Bhavan

Annexure II shows design outlines supplied by the air-conditioning divisions of Voltas and Blue Star. Voltas gave a quotation for centrally air-conditioning the whole of Shram Shakti Bhavan, while Blude Star gave a quotation for centrally air-conditioning the second floor only. It must be mentioned that there is a substantial difference in designs in the capacity and cost quoted. A cost benefit analysis for each of the two designs was computed but was not found to be economically viable.

Bhavan. After one hour of operation, there was no measurable change in room temperature, while the air-conditioner consumed 2.8 kWh of electricity. The measurement was made in March when ambient temperature was 24.4°C. Unless repaired, this air-conditioner will consume approximately 3326 kWh per cooling season, without any effective cooling.

The Need for Existing Central Air-conditioner System

Six package air-conditioner units of 7.5 tons cooling capacity each have been installed on the ground floor at Shram Shakti Bhavan. Four of these units work from about 8.30 a.m. to 8.00 p.m. daily, while two are kept as standby. This system serves seven rooms, three on the second floor and four on the first floor. The units also have 18 kW of resistance heaters which are used in winter. However, the blower (5 hp rating) operates throughout the year to provide ventilation. Table 4.10 shows estimated energy requirement of the system. These seven rooms typically have a cooling load of 2.53 tons each (see section 4.2.4).

Table 4.10: Electricity required by central air-conditioning system installed at Shram Shakti Bhavan

Mode	Electricity Requirement (Units/hr)
Cooling	31.6*
Heating	21.73
Ventilation	3.73

* Assumes all compressors are running and includes cooling tower pumps.

Six of the seven rooms were visited and it was observed that in addition to central air-conditioning supply, five rooms have two window air-conditioning units each. In the remaining room, the central air-conditioning ducts had been boarded up and it was air-conditioned by three window air-conditioners. This room is actually two rooms with the partition removed and has 1600 W of installed incandescent lighting, (but has solar film on the windows to offset some of the direct solar gain). The air-conditioning load based on ASHRAE methods works out to 4.2 tons.

Table 4.11 : Energy conservation opportunities in air-conditioning

Recommendation	Reduction in annual energy consumption		Estimated investment	Approximate payback period
	kWh	Rs.	Rs.	Yrs.
Regular cleaning of filters on window air-conditioner	122.4^{+}	183.6	Nil^{++}	Immediate
Repair of non-functioning	1152^{+}	1728	Nil^{++}	Immediate
Shutting down of existing central air-conditioning plant	44623*	66934	Nil^{++}	Immediate

Others

Regular testing of thermostat in window air-conditioner
Regular check for coolant leakage in window air-conditioner
Establish 25°C as optimum cooling level by installing thermometers on desks

Savings per air-conditioner per cooling season
Annual energy savings
Part of existing maintenance contract

4.3 Desert coolers

The following observations and recommendations would help in increasing the efficiency of cooling by desert coolers.

Coolers must be placed such that they can humidify (and therefore cool) **outside** air and push it into the room.

Many coolers were found placed on tables within rooms. This will only cause over humidification and increased discomforts to occupants. Proper placement of packing (khas khas, which provides area of contact for humidification) is necessary for effective humidification to take place. It should be ensured that it does not settle down with weight of water, resulting in large gaps through which hot air can flow in.

Packings should be replaced every year, else the dust collected would hinder required air flow.

Table 4.12 : Energy conservation measures for coolers

- Place coolers such that they can draw **outside air**
- Replace packing every cooling season

Since isolated positions of Shram Shakti Bhavan require air-conditioning, it is preferable to use window units, since they can provide cooling and/or heating when required, at the location. This is more efficient from an energy point of view.

4.2.9. Some General Comments

The audit team observed that whenever a senior official or a minister took charge, often there were changes made in the interior of the rooms. This included change in the furniture, curtains, lighting and also replacing some of the older air-conditioners with new ones. The older air-conditioner was generally sent down to another room which do not have an air-conditioner. Incidentally, the room where the air-conditioner is re-located happens to be either a Director's office or a Deputy Secretary's office. It is important to note that the air-conditioner is re-located in an 'as is where is' condition. While agreeing with the official view that the air-conditioner is a surplus, and hence instead of lying and deteriorating in the stores, it makes sence to locate it in a room where it could be used. From the point of view of energy conservation, our recommendation is that the air-conditioner must be thoroughly overhauled before it is re-located. This practice of overhauling the air-conditioner whenever it is re-located, should become a point of the procedures followed while re-locating. This will ensure that the air-conditioner operates at a reasonable level of efficiency.

4.4.3 Replacing Radiant Heaters with Convective Heaters

Radiant heaters do not provide effective space heating for all the occupants of a room, since heat transfer takes place mainly by radiation. On the other hand, a convective heater serves to warm up the air inside a room, providing a higher level of comfort for all the room occupants. Convectors (convective heaters) cost more (approx. Rs. 500 per piece) than radiant heaters (about Rs. 150 each).

There are 47 rooms in SSB which have at least 2 single rod (1kW) radiant heaters. Together, these 47 rooms have 111 single rod heaters. If we assume that every two single rod radiant heaters are replaced by one single coil convective heater of 1.2 kW rating, an annual energy savings of 26,532 kWh is possible. The payback for purchasing 55 convectors works out to less than one heating season. These calculations are shown below in Table 4.13.

Table 4.13 : Replacement of two single rod heaters with one convector

No. of rooms having more than one single rod radiant heater = 47

Total No. of heaters in above rooms = 111

Installed kW Rating = 111

Replace 2 single rod heaters with one convector (1.2 kW) = 55 convectors

Assume convector coil draws power for 2/3 of operative time due to thermostat operation.

Heater type	No. of heaters	day/month	hrs/day	winter months	rating	energy used
Single rod	111	22	9	2	1	43,956
convector	55	22	9	2	1.2x(2/3)	17,424

Energy saved 26,532 kWh

Cost of Energy saved Rs. 39,798

Cost of 55 convective heaters = Rs. 27,500
Payback period = 0.7 years

4.4 Room heaters

Three types of room heaters are used in Shram Shakti Bhavan. These are (1) Convector (convective heaters), (2) twin rod (radiation) heaters and (3) single rod heaters. Seventeen coil type heaters, used for making tea were also found in the building.

Relevent data on the heaters was collected by visual observation and carrying out measurements on selected samples. Table 3.2 in chapter 3 gives the floorwise distribution of heater by type.

4.4.1 Observations

About 150 heaters had dirty reflectors, while only 19 heaters had clean reflectors. Heating was inadequate (effective heating was not observed beyond one meter distance from the heater in most of the cases) because of dirty reflectors.

Major cause of reflectors becoming dirty was due to inadequate maintenance, and use of room heaters to heat lunch boxes.

Heaters were switched on even when the day temperature was warm enough (temperature greater than 18°C)

Building occupants often did not turn the heater off when leaving the room during lunch and other intervals.

4.4.2 Recommendations

Periodic cleaning of the reflectors is necessary to ensure effective heating. Reflectors must be cleaned just before the heating season, in early November, and should be dusted weekly by peons.

Building occupants must be discouraged from using heaters for heating lunch boxes. Unless an effective alternative, e.g. hot cases (or hot boxes) are provided, it will be difficult to implement such a directive.

Creating public awareness about energy conservation with special reference to the use heatings with the help of charts etc., with help in reducing energy consumption.

Since convectors are more effective and use less electrical energy, all future issues of heaters should be of convective type.

Table 4.15 : **Energy conservation opportunities in heating**

Recommendation	Reduction in annual energy consumption		Estimated investment	Approximate payback period
	kWh	Rs.	Rs.	Yrs.
Replace two (1 kW) radiant heaters (in a room) with one convector	26,532	39,798	27,500	0.7
Replace twin-rod (2 kW) radiant by convectors	10,930	16,395	11,500	0.7

Other Measures

- o Periodic cleaning of heater reflectors
- o Future issue of heaters restricted to convector type
- o Create public awareness for energy conservation

4.5 Lifts and Other Equipments

The equipment load in Shram Shakti Bhavan is about 130 kW which is about 14.1 per cent of the total load. This includes the load due to computers, xerox machines, electric/electronic typewriters, lifts and overhead tank water pumps. A listing of equipment is given in Appendix I. It has been estimated that electricity consumed in the equipment load is about 22.1 per cent of the total electricity consumption.

The lifts installed in Shram Shakti Bhavan are very old and it may be required to replace them. Lifts presently available have several advantages over lifts manufactured in the past. Unlike old lifts, new lifts are provided wih variable speed alternating current motors with microprocessor control which considerably improve their performance. The cabin cars are better designed and the speed of operation is higher. New lifts may not be more energy efficient than the old one's in terms of energy consumption, since the emphasis has been more on improvement in performance and comfort. However, there might be some reduction in electricity consumption but it would be difficult to quantify the savings.

The electricity consumption in the equipment load could be reduced by ensuring that xerox machines and electric/electronic typewriters are switched off when not in use. This could be brought about mainly by awareness among personnel. Since the hours of operation of these equipment is dependant upon the work load, it is difficult to quantify the savings that could be achieved.

The replacement of heaters should be done on a case by case basis, since very large rooms will need more than one heater to provide effective heating.

In addition to more effective heating, convective heaters cannot be used for heating up of food, and therfore will help in energy conservation. It is recommended that only convective type heaters be issued to building occupants in future.

4.4.4 Replacing Twin Rod Radiant Heaters by Convective Heaters

Since convective heaters are more efficient when compared to radiant heaters, one may think of replacing the 23 twin rod radiant heaters in Shram Shakti Bhavan with convective heaters of 1.2 kW rating. The calculation procedure is similar to that in the previous section and are given in Table 4.14. The estimated energy savings work out to 10,930 kWh and the payback period for replacement is less than one heating season.

Table 4.14 : Replacing twin-rod heaters with convectors

Rating for each twin rod radiant heater = 2 kW

Rating for each convective heater = 1.2 kW
Asssume convective heater draws power for 2/3 of time due to controlling action of thermostat.

Type	no.	day/month	hrs/day	Winter months	Rating	Thermo- stat	Energy used
Twin rod	23	22	9	2	2	-	18,216
Convector	23	22	9	2	1.2	2/3	7,286
					Energy saved		10,930 kWh
					Cost of energy saved Rs.		16,395

Cost of 23 convector heaters = Rs. 11,500
Pay back period = 0.7 years.

CHAPTER 5
INSTRUMENTATION AND CONTROLS

5.1 Instrumentation

For a continuously effective energy management program it is necessary to be able to gather accurate data. This requires accurate and appropriate instrumentation along with trained personnel to monitor the instruments. A well designed energy accounting system will ensure meaningful energy accounting with minimum data.

5.1.1 Appropriate instrumentation

The high tension incoming feeder at the Shram Shakti Bhavan sub-station is split into two before being connected to two separate 750 kVA transformers, one each for Transport Bhavan and Shram Shakti Bhavan. The ammeter on the single feeder has a lower range than the ammeters of the split feeders which must carry less current. We recommend that these be replaced with instruments of appropriate ranges for more effective monitoring.

The CPWD is connecting an energy meter on the low tension side bus bar of Shram Shakti Bhavan. This meter, along with the existing meter on the low tension side of Transport Bhavan will be a check on the high tension NDMC meter.

5.2 Switching and controls

Controls are recommended at two levels. i.e. macro level and micro level.

5.2.1 Macro level controls

Switching controls at the building or individual floor level can be termed macro level control. We recommend the following control strategies be studied by the CPWD for their feasibility.

5.2.1.1. Floor-wise master switching for power points

To avoid wastage of energy due to building occupants forgetting to switch off power equipment like air-conditioners, heaters etc., the power circuitry of each floor should be connected through master switches which are operated manually to switch off electricity, say after 9 p.m. and switched on at 7.00 or 7.30 a.m. Alternately, these master switches could be controlled through a microprocessor based battery powered timer. Such systems can be programmed to take care of special

situated in almost inaccessible locations i.e. behind shelves, or in the corner, between sofas etc. This needs to be looked into on an urgent basis for this would be the first step in assisting people in implementing conservation measures. It is understandable that building occupants do not take the trouble to switch off equipment and lights when they go out.

We strongly recommend installation of master switches just outside the door for all rooms which have two or more air-conditioners. The attendants of these rooms should be instructed to switch the power off, when the officer concerned is away for meetings (say for an hour or so). Master switches should also be provided for large section halls where two or more coolers/heaters are in use. During discussions with CPWD officials we found that such a scheme had already been proposed by them. We recommend that the proposal be revised and acted upon without further delay.

An important point to note is that all the controls installed would be effective only if they are maintained in working condition. In addition, a systematic maintenance schedule for the equipment is an essential part of a good energy management control system. It is a well established fact that good housekeeping and proper maintenance alone brings about upto 10 per cent reduction in energy consumption. It is imperative that a regular maintenance schedule is drawn up for all the equipment in the building and duly implemented.

schedules for weekends and `budget rush' days. Enquiri revealed that presently, all rooms are locked at nigh and are again opened the next day. Instructions shoul be given to the persons who do the locking, to ensu that no appliances are on, when they lock the room.

The installation of floor-wise switches would mea substantial rewiring of connections, to group a connections in one floor/wing to distribution boxes o that floor. Even though this would initially mean high costs, in the interest of safety and house-keeping, it i recommended that this be done.

5.2.1.2. Automatic control of central HVAC system

The same system can be used to automaticall control the central heating, ventilating and ai conditioning (HVAC) system used for space conditioning c the second floor. Since the system will wor automatically between fixed timings, energy wastage du to operator error can be eliminated.

Our recommendation for a review into the need f the central air-conditioner plant should be carried o before going into automatic control of air-conditioni system.

5.2.1.3. Central control of corridor and toilet lights

As seen from Chapter 3, substantial energy savings are possible by judicious management of the lighting system. Corridor and toilet lights should be connected such that all toilet lights and half the corridor lights can be switched off by the timer system discussed above. The remaining corridor lights should be connected on a 24 hour basis, and should be controlled from the CPWD office on the ground floor.

5.2.2. Micro level switching

Location of switches within a room determines the leve of energy wastage. The harder it is to reach the switch the greater the chance that occupants will leave equipment and lights on while making short trips within the building

Most rooms in Shram Shakti Bhavan have light and powe switches located at inaccessible places behind shelves o files near the floor. The physical audit showed that ou of 263 rooms, only four per cent of the switch boards wer located in very easily accessible positions i.e. th occupant can switch off the lights/fans on his way out. A against this, 30 per cent of the switch-boards wer easier for employees to understand kilowatt hour, if kilowatt hour or unit is converted to electricity to burn lamps, to run refrigerators or their fans/coolers, or even convert to money value, which would make real sense.

We must remember that the basic objective of the awareness programme is to bring about a change in the attitude of the people to energy conservation. It is a difficult task convincing people that energy is being used inefficiently. The awareness programme must highlight the positive aspects of saving energy and emphasize on the need for participation of all concerned, to make the programme a success. Getting people to change their habits and become aware of energy wastage, especially when they are not personally paying for it, is an extremely difficult task. As already mentioned in the earlier chapters, the audit team came across peons relaxing in officers' rooms with air-conditioners on, when the officers were either out of town or away for meetings. It is important that steps are taken to stop this practice.

CHAPTER 6
PUBLIC AWARENESS

Publicity and promotion are essential ingredients of a successful energy management programme. They are very important for motivating people in a building to save energy. It is difficult to separate publicity and promotion from motivation because the primary purpose of both is to make people want, to accept and to encourage energy conservation. It is a form of advertising, getting the employees to buy the product of energy conservation. Listed below are some recommendations for publicizing and promoting an energy management programme in the Shram Shakti Bhavan:

1. Display on the notice boards a personal profile on people performing energy management activities and at least one good energy conservation idea that was implemented.
2. Posters and pamphlets on energy conservation.
3. Appointment of energy coordinators on each floor of the building.
4. One Joint Secretary of each department located in the building assuming direct responsibility for energy management, publicity and promotion of energy conservation.
5. Quarterly meetings of all the coordinators and energy awareness day twice a year, list do's and don'ts in each of the offices prominently displayed.
6. Make effective use of stickers, cartoons, posters, etc. to highlight importance of saving energy; stickers saying "turn-off lights when not required", on switch boards.
7. Display of charts showing how electricity consumption changes from month to month indicating improvements (savings, if any).
8. A short film on how energy can be saved in the building to be used to increase awareness in the building occupants.

The energy coordinators would be responsible for ensuring that energy conservation is practised on every floor of the building. If there are difficulties in implementation, they would find solutions to the problems. The coordinators would closely monitor energy consumption and report these to the Joint Secretaries concerned. The Secretaries of each department would have a role in reviewing the energy management programme in the building and ensuring that electricity is saved, wastage avoided as well as to maintain electricity savings once attained.

The awareness programme should use terms that employees in the building can relate to in everyday life. For example, it is

Summary of Recommendations for Energy Conservation at Shram Shakti Bhavan

No Cost Measures

Section No.	Recommendation	Reduction in annual energy consumption kWh	Reduction in annual energy consumption Rs.	Estimated investment Rs.	Approximate payback period Yrs.
4.2.7	Shutting down existing central air-conditioning plant	44,623	66,934.5	Nil	Immediate
3.5	Improved overnight housekeeping; making sure all equipment, lights etc. in rooms are switched off by 8.00 p.m. every evening	39,000	58,500	Nil	Immediate
3.4	Switching off tubelights in toilets, main lobby and staircases during daytime	3,724	5,587	Nil	Immediate
4.2.5	Repair of non-functioning thermostats on windiw air-conditioners	1,152^{+}	1,728	Nil**	Immediate
4.2.2	Regular cleaning of filters on window air-conditioners	122^{+}	184	Nil**	Immediate

+ Savings per air-conditioner per cooling season

** Can be made part of existing maintenance contract

Low[+] Cost Measures

Section No.	Recommendation	Reduction in annual energy consumption kWh	Rs.	Estimated investment Rs.	Approximate payback period Yrs.
3.5 and 3.6	Rewiring alternate lights on corridors to one control switch (assured saving)	36,139	54,209	49,000	0.92
4.4.3	Replace two (1 kW) radiant heaters (in a room) with one convector	26,532	39,798	27,500	0.7
4.1.2.3	Replace existing 40W fluorescent tubes with 36W slimline type	15,088	22,632	36,000	1.6
3.3	Provide hot cases for warming lunch	11,836	17,754	21,000	1.18
4.4.4	Replace twin-rod (2 kW) radiant heaters with convectors	10,930	16,395	11,500	0.7
4.1.2.7	Replace existing incandescent lamps with compact fluorescent lamps	5,498	8,247	7,800	0.95

+ investment upto Rs. 50,000 and payback in less than two years

/contd./

High Cost Measures

Section No.	Recommendation	Reduction in annual energy consumption kWh	Rs.	Estimated investment Rs.	Approximate payback period Yrs.
4.1.2.4	Replace existing poor quality chokes with high efficiency chokes	28,264	42,396	97,500	2.3
	or				
4.1.2.5	Replace existing poor quality chokes with good quality electronic chokes	80,079	1,20,119	2,16,000	1.8

/contd./

Other Measures

Section No.	
3.1	Re-conditioning of electrical system
4.1.2.1	Enhance natural lighting by cleaning windows, daylight shelf
4.1.2.2	Clean light fixtures every six months
4.1.2.3	Maintain illumination level by following a regular relamping scheme
4.2.4	Establish 25°C as optimum cooling level by installing thermometers on desks
4.2.5	Regular testing of thermostat in window air-conditioner
4.2.6	Regular check for coolant leakage in window air-conditioner
4.4.2	Periodic cleaning of heater reflectors
4.4.2	Future issue of heaters restricted to convector type
6	Create awareness for energy conservation

Annexure - I

Summary of Physical Audit at Shram Shakti Bhavan

FLOOR NO	A/C	HEATER TYPE				FLT	FANS	COOLER			TABLES	ROOM
		Single	Twin	Convector	Coil			small	med	large		
0	20	15	4	2	5	156	23	11	3	5	177	30
1	12	19	2	10	0	172	92	4	1	2	113	35
2	24	18	1	18	2	274	152	0	5	6	136	36
3	0	33	0	15	0	154	111	10	3	6	112	39
4	26	24	2	24	2	213	117	10	1	27	183	38
5	2	26	5	7	4	98	105	21	1	0	199	36
6	1	49	7	5	3	152	121	11	27	1	271	43
Annexe	0	22	2	1	1	111	123	31	13	5	127	35
Exterior						30						
Corridor						120						
Toilets						57						
Total	85	206	23	82	17	1537	844	98	54	52	1318	292

A/C - window air-conditioner
FLT - fluorescent tubelights
ROOM - no. of rooms visited on respective floor
(approximately five rooms were locked)

Equipment at Shram Shakti Bhavan

Sr. No.	Equipment	Number	Rating
1	Lifts	4	11 kW
2	Overhead Tank Pump (only one pump operator at a time)	3	7.5 kW
3	Central a/c		
	Compressors	4+2*	7.5 hp
	Heater	-	18 kW
	Blower	-	2.2 kW
	Pumps	3	1 hp
4	Computer terminals (includes PC's and 1 mini computer)	85	-
5	Photocopy machines	18	300-350 W
6.	Electric/ Electronic typewriters	25	

* Standby

Annexure - II

Quotation and Preliminary Design of Central Air-condition System for Shram Shakti Bhavan

VOLTAS LIMITED

AIRCOND. & REFRIG. CENTRAL PLANTS DIVISION

7/1, Asaf Ali Road,
Post Box 385,
New Delhi - 110 002
Phones: 730221 (8 Lines), 731018
732316, 733128
Telex : 031-62524, 62368
Grams : VOLTAS

Ref.: ACR/86042/SG

Date : 20th April, 1989.

Tata Energy Research Institute
232, Jor Bagh
NEW DELHI 110 003.

Attn : Mr. BHASKAR NATARAJAN.

Dear Sirs,

SUB : Air conditioning of Shram Sakthi Bhavan, Rafi Marg, New Delhi 110 001.

We refer to your letter dated 13th February, 1989 and the subsequent discussion we had with you in connection with the above.

As desired by you, we are pleased to give hereunder our budgetary offer for the above air conditioning work.

1. BASIS OF DESIGN :

Area to be air conditioned : Ground + 1st + 2nd + 3rd + 4th + 5th + 6th.
: 1,640 sq.mt each.

Occupancy : 150 person each floor

Lights : 10 watt/ sq.mt

Appliances : Nil

2. DESIGN CONDITIONS :

	Temp. Dry Bulb (°C)	Temp. Wet Bulb (°C)	Relative Humidity (%)
Outside : Summer/ Monsoon/Winter :	43.3/35/7.2	23.9/28.3/5	--
Inside : Summer & Monsoon :	24 ± 2.0	--	--

..contd..2/-..

Make of Water requirement	: Soft and clean water must be made available by you at the rate of 9,000 litres per hour
Electric Power Requirement	: 750 KW Approximately of 415 V 3 Phase 50 Hz., 4 Wire AC Supply.

2. SCHEME :

Based on the above design conditions, the total air conditioning load works out to 525 TR. To cater to this load requirement, we propose installation of the following :

1.	120 TR Nominal Capacity reciprocating VOLTAS water chilling machine comprising of Compressor Model 05126 Condenser Model 09127 Chiller Model 11150	...... 5 Nos.
2.	Horizontal split casing condenser water pumpsets	...... 6 Nos. (1 standby)
3.	Horizontal split casing chilled water pumpsets	...... 6 Nos. (1 standby)
4.	VOLTAS FRP Cooling Tower of 300 TR Nominal capacity	...... 2 Nos.
5.	AHU Model AH-9/CWC 9/4R/130 comprising fan section with fan, coil section with cooling coil, filter section with filters.	......21 Nos. (3 Nos. each floor)
6.	Ducting, insulation, grilles/ diffusers......	LOT
7.	Condenser water piping with fittings & valves	LOT
8.	Chilled water piping duly insulated having fittings & valves	LOT
9.	Associated electrical work	LOT

..contd..3/

3. CONTRACT VALUE (BUDGETARY) :

Our price for supply, installation and commissioning of the above item at site on individual works contract basis shall be Rs.1,75,00,000/- (Rupees one crore seventy five lacs only).

4. ITEMS NOT INCLUDED :

The contract value indicated above includes only the items of work specifically mentioned. All other ancillary works explained in brief hereunder will have to be arranged for by you.

a. All masonry work such as supports for the cooling tower, foundation for all the equipment, housing for the equipment, cutting away and making good of walls and floor slabs etc.

b. Supply and installation of main power connection alongwith main earthing terminating in our switchboard in the plant room and AHU romm.

c. Make-up and drain of condenser water.

d. All false ceilings, enclosures or plenums around ducts, insulation work of any kind (other than that specifically included under DESCRIPTION OF THE WORK above), acoustic treatment to the plant-room, wooden frame work for fixing the grilles and painting.

e. Protected storage space at site.

f. Power and water for erection, testing and commissioning of the plant.

g. Water softening plant, if required.

h. Exhaust arrangement in the plant-room.

..contd..4/-..

5. COMPLETION PERIOD :

The entire contract works are due to be completed within ten to twelve months from the date of receipt of your order alongwith down payment.

We trust you will find the above information sufficient to meet the budgetary requirement. We shall be pleased to submit our detailed offer on further hearing from you.

Thanking you and assuring you of our best attention always,

Yours truly
VOLTAS LIMITED
By Its Constituted Attorney

(BIDYUT CHATTOPADHYAY)

vs

BLUE STAR

Blue Star Limited
91, Nehru Place, Bhandari House, New Delhi 110 019 • Telephone 643 25 47 & 643 29 70 • Telegrams BLUESTAR • Telex 031-66063

OUR REF : VSA/021/GEN/I

April 20, 1989

M/s Tata Energy Research Institute.,
7, Jor Bagh,
New Delhi - 110 003

Kind Attention Mr. P C Thomas

Subject; Your air conditioning requirement at Shram Shakti Bhawan.

Dear Sir;

This is with reference to the discussions the undersigned had with you regarding the subject job. To meet your requirement, we propose to instal 5 Nos water cooled packaged units each of capacity 7.5 TR and 2 Nos water cooled packaged units each of capacity 10 TR for each floor thus amounting to an agreegate of 57.5 Tons.

The total power consumption of the system offered by us shall be 56 KW. The total area to be air conditioned on each floor shall be as per the drawing except the Toilet, Staircases and the Kitchen.

Our budgetory price for supply, installation, testing and commissioning of the equipment/material including cooling tower, pump, ducting, grilles/diffusers, piping and electrical work etc. shall be Rs. 14,40,000/- (Rupees fourteen lacs and ~~fourteen thousand~~ forty thousand only). This price is based on the currently applicable taxes and duties.

We hope you find the above in line with your requirement. In case you require any further information/clarification, please feel free to contact us at your convenience.

Thanking you and assuring you of our best attention at all times.

Very truly yours
BLUE STAR LIMITED

VIRENDRA SAPRA
SENIOR ENGINEER
AC & R PROJECTS DIVISION

Registered Office: Kasturi Buildings, Jamshedji Tata Road, Bombay 400 020

Annexure - III

Existing Lighting System in a Typical South Facing Room

```
=========================================================================
ILIPS LIGHTING B.V.                          ! Computer Aided Lighting Design
ghting Design and Engineering Centre         ! I N D O O R  1.02   October 88
mputer Aided Lighting Design                 ! Philips Lighting B.V.
-------------------------------------------------------------------------
oject name          : S S B
oject number        : R. NO. 223
signer              : LP
=========================================================================


ighting calculations
--------------------


oom dimensions         :  Length                     [m] :          5.90
                          Width                      [m] :          4.10
                          Height                     [m] :          2.50
                          Working plane height       [m] :          0.70


oom reflectances       :  Ceiling                        :          0.50
                          Walls                          :          0.50
                          Floor                          :          0.10


uminaire data          :  Luminaire reference no.        :          1023
                          Measuring code                 :             ?
                          Luminaire type                 :    TCS 31/236
                          Lamp type                      :      TLD 36W
                          No. of lamps                   :             2
                          Lamp flux             [klumen] :          2.50
                          Luminaire wattage          [W] :         96.00
                          Orientation                    :     Crosswise


nstallation data       :  Required illuminance [lux]     :           250
                          Maintenance factor             :          0.75


lluminance values      :  Initial                  [lux] :           210
                          Maintained               [lux] :           157


lso calculated         :  Utilisation factor     (CIE)   :          0.51
                          Power/sqr.mtr.          [W/m2] :          7.94
                          Total installed           [kW] :          0.19


lumber of luminaires   :  Lengthwise                     :             2
                          Crosswise                      :             1
                          Total                          :             2
```

```
===========================================================================
LIPS LIGHTING B.V.                     | Computer Aided Lighting Design
ghting Design and Engineering Centre   | I N D O O R  1.02   October 88
mputer Aided Lighting Design           | Philips Lighting B.V.
---------------------------------------------------------------------------
oject name          : S S B
oject number        : R. NO. 223
signer              : LP
===========================================================================


int calculations
----------------

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
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                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
                                                                           3
DDDDDDDDDDDDDDDDDDDDDDDDD Length : 5.9 --> Y DDDDDDDDDDDDDDDDDDDDDDDDDDDDDY


inaires                 :  Start position     X0 [m] :            2.050
                                              Y0 [m] :            1.475
                           Distance           dX [m] :            4.100
                                              dY [m] :            2.950
                           Number of          NX [m] :                1
                                              NY [m] :                2
```

```
:=====================================================================
ILIPS LIGHTING B.V.                        ! Computer Aided Lighting Design
ghting Design and Engineering Centre       ! I N D O O R  1.02   October 88
mputer Aided Lighting Design               ! Philips Lighting B.V.
----------------------------------------------------------------------
oject name          : S S B
oject number        : R. NO. 223
signer              : LP
======================================================================


sults of point calculations at working plane height
------------------------------------------------------



tal horizontal illuminance in lux
-----------------------------------

[m] 0.3   0.8   1.3   1.9   2.4   2.9   3.5   4.0   4.6   5.1   5.6

[m]
81    88    98    92   107   122   125   122   107    92    98    88

22   131   155   148   170   191   193   191   170   148   155   131

64   191   233   221   244   284   277   284   244   221   233   191

05   224   281   267   294   328   325   328   294   267   281   224

46   191   233   221   244   284   277   284   244   221   233   191

88   131   155   148   170   191   193   191   170   148   155   131

29    88    98    92   107   122   125   122   107    92    98    88


average)  :   184      Lux
in/Emax   :     0.27
in/Eaver  :     0.48
```

Annexure - IV

Optimized Design for Typical Section Hall

```
=========================================================================
PHILIPS LIGHTING B.V.
Lighting Design and Engineering Centre   ! Computer Aided Lighting Design
Computer Aided Lighting Design           ! I N D O O R  1.02   October 8
                                         ! Philips Lighting B.V.
-------------------------------------------------------------------------
Project name          : S S B
Project number        : R. NO. 22  SECTION HALL
Designer              : LP
=========================================================================


Lighting calculations
---------------------


Room dimensions            :  Length                      [m] :      11.80
                              Width                       [m] :       4.10
                              Height                      [m] :       2.90
                              Working plane height        [m] :       0.70


oom reflectances           :  Ceiling                         :       0.50
                              Walls                           :       0.5
                              Floor                           :       0.10


Luminaire data             :  Luminaire reference no.         :       102
                              Measuring code                  :
                              Luminaire type                  :  TCS 31/23
                              amp type                        :    TLD 36W
                              No. of lamps                    :
                              Lamp flux              [klumen] :       2.50
                              Luminaire wattage           [W] :      96.00
                              Orientation                     :  Crosswise


Installation data          :  Required illuminance [lux] :            200
                              Maintenance factor              :       0.75


Illuminance values         :  Initial                   [lux] :        318
                              Maintained                [lux] :        238


Also calculated            :  Utilisation factor       (CIE) :        0.51
                              Power/sqr.mtr.          [W/m2] :       11.91
                              Total installed           [kW] :        0.58


Number of luminaires       :  Lengthwise                      :          3
                              Crosswise                       :          2
                              Total                           :          6
```

```
===================================================================
HILIPS LIGHTING B.V.                   | Computer Aided Lighting Design
ighting Design and Engineering Centre  | I N D O O R  1.02   October 88
omputer Aided Lighting Design          | Philips Lighting B.V.
-------------------------------------------------------------------
roject name        : S S B
roject number      : R. NO. 222 SECTION HALL
esigner            : LP
===================================================================


oint calculations
-----------------

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD:DDDDDDDDD?
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
X                                                                  3
.                                                                  3
|                                                                  3
.                                                                  3
i                                                                  3
d                                                                  3
t                                                                  3
h                                                                  3
3                                                                  3
                                                                   3
.                                                                  3
i                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
3                                                                  3
@DDDDDDDDDDDDDDDDDDDDDDDDD Length : 11.8 --> Y DDDDDDDDDDDDDDE:DDDDDDDDDDDY


Luminaires                 Start position      XO [m] :            1.055
                                               YO [m] :            2.950
                           Distance            dX [m] :            2.050
                                               dY [m] :            2.950
                           Number of           NX [m] :
                                               N  [m] :
```

```
==========================================================================
HILIPS LIGHTING B.V.                         ! Computer Aided Lighting Design
ghting Design and Engineering Centre         ! I N D O O R  1.02   October 88
omputer Aided Lighting Design                ! Philips Lighting B.V.
--------------------------------------------------------------------------
roject name          : S S B
roject number        : R. NO. 222  SECTION HALL
esigner              : LP
==========================================================================
                                      - 3 -            Date    : 89-03-07

esults of point calculations at working plane height
---------------------------------------------------



otal horizontal illuminance in lux
----------------------------------

 [m] 0.4  1.3  2.1  2.9  3.8  4.6  5.5  6.3  7.2  8.0  8.9  9.7 10.5 11.4

 [m]
.81   94  159  213  214  283  311  260  260  311  283  214  213  159   94

.22  104  189  260  262  347  379  319  319  379  347  262  260  189  104

.64  110  200  281  278  377  405  344  344  405  377  278  281  200  110

.05  113  203  276  278  376  409  347  347  409  376  278  278  203  113

.46  110  200  279  277  374  403  343  343  403  374  277  279  200  110

.88  103  186  256  259  341  373  315  315  373  341  259  256  186  103

.29   93  156  207  208  275  302  253  253  302  275  208  207  156   93


 (average)   :   259       Lux
 min/Emax    :     0.23
 min/Eaver   :     0.36
```